CABRILLO PORT, LNG TERMINAL PROJECT
Document Title: Seawater Cooling Elimination
Document No.: WCLNG-BHP-DEO-UR-00-311-0
Revision No.: D
Issue Date: 19 June 2006

WorleyParsons bhpbilliton

Project Title:	Subject:
CABRILLO PORT LNG TERMINAL	**Seawater Cooling Elimination.**

Report : Seawater Cooling Elimination
BHPB Document No. WCLNG-BHP-DEO-UR-00-311-0

WorleyParsons Document No. 05876-PR-TN-016

D	19/06/06	Plume Dispersion Included	PJP	JS	BP
C	7/06/06	Issued for Client	PJP	JS	BP
B	1/06/06	Re-Issued for review	PJP	JS	BP
A	11/05/06	Issued for review	PJP	JS	BP
Rev.	Date	Description	Produced by	Checked	Appr'd

BHP Billiton LNG International Inc.	WorleyParsons Project No. 351/05876

Table of Contents

1 EXECUTIVE SUMMARY

WorleyParsons assessed the feasibility of reducing the seawater intake and discharge as engine room cooling water under normal operation. It was determined that a closed-loop tempered water system could be used in place of the current seawater cooling system, eliminating the requirement for seawater cooling under normal operation. BHPB have therefore amended the cooling system design to incorporate these findings as a direct mitigation measure in response to the US Agency concerns on cooling water discharge.

The tempered water loop will transfer heat energy generated by engine room equipment to the LNG vaporisers (SCVs) This heat recovery option has the additional benefit of reducing fuel gas consumption by 4% (0.5 MMscfd), air emissions and SCV water disposal by 4%. The CAPEX has been estimated at $US 5 Million ±25%; reduction in OPEX could not be estimated.

The use of a tempered water loop between the engine room and the SCV bath water requires modifications to standard vendor packages; however the vendors of SCVs have confirmed that they are investigating similar heat integration schemes in existing facilities with other customers.

The changes will reduce the current seawater cooling system from a continuously operating system to an intermittent back up system, thus reducing the seawater intake and discharge, and reducing the impact to the marine environment. For an estimated SCVs reliability of 99%, the SCVs are offline a total of 4days per year. The Inert Gas Generator (IGG) system is a separate seawater system and will only operate for a total of 4days per year for tank inerting. These systems are independent and will not operate simultaneously.

Plume dispersion models have been completed for the intermittent operations when the SCVs are offline and back up seawater cooling is required, as well as the four day period per year when the IGGs are required for tank inerting. Models were based on the 1 year maximum current (1.35 knots) and half of the 1 year maximum current (0.675 knots), the latter being the more realistic scenario as the as the annual average current is 0.25 knots.

Modelling for 1 year maximum current shows the discharge seawater temperature cools to 4°C within 250 meters (7°F within 850 ft) of the discharge point and to 2°C within 1500 meters (4°F within 5000 ft) from the discharge point.

At half of the 1 year maximum current modelling shows the discharge seawater temperature cools to 2°C within 225 meters (4°F within 750 ft) of the discharge point and to just over 1°C within 1000 meters (2°F within 3300 ft) from the discharge point. This is a more realistic scenario and complies with the Californian Thermal Plan since the probability of SCV upset or IGG use coinciding with the worst current of the year is very low.

2 INTRODUCTION

The objective of this study is to evaluate and confirm the feasibility of reducing the intake and discharge of seawater on the FSRU for the purpose of engine room equipment cooling. Although seawater cooling is standard marine practice the calculated thermal discharge plumes from the FSRU did not meet the US EPA requirements. The recent draft Environmental Impact Statement (EIS)/EIR and National Pollutant Discharge Elimination System (NPDES) permit acknowledges that the thermal discharge from the FSRU just fails to meet the requirements of the California Thermal Plan, with regard to exit temperature.

The effect of injecting chemicals into the seawater cooling system for marine growth inhibition also has an impact on marine life.

FSRU seawater cooling system (located in the engine room) removes the heat generated by the Wartsila power generators, fresh water maker, HVAC system and other equipment. Seawater is taken from sea chests located below the hull and the warm water is discharged off the side of the FSRU below the water line. The original project intent was to use proven technology thus standard marine design principles were used.

The system modification involves the use of a closed loop tempered water system that will transfer the heat recovered in the engine room into the water bath of the SCVs (LNG vaporizers) located in the forward deck.

3 BASIS AND ASSUMPTIONS

The assumptions made in this assessment are:

1) The SCVs have an availability of 99%, allowing for maintenance, inadvertent shutdowns and other activities that require the SCVs to be offline. A backup seawater cooling system will remove heat from the tempered water loop when the SCVs are offline for a total of an estimated 4 days per year.
2) The IGG is a separate system to the SCV and cooling water system, and will require its own seawater cooling. The IGG is not a continuous user with the proposed operational period of 4 days per year when tanks are inerted for preparation for inspection. The IGG has therefore been excluded from the Tempered Water Loop review, however is included separately in the seawater plume dispersion model. It is important to note that when the seawater back up system is running the IGG will not operate and vice versa.
3) It is estimated that the 2 x 100% tempered water pumps and the SCV circulation pumps have the same total electrical load as the seawater back up pumps.
4) Equipment for the new system has been sized for maximum capacity (future expansion case). The discharge and emission reductions have been based on 800 MMscfd gas export (normal operation).

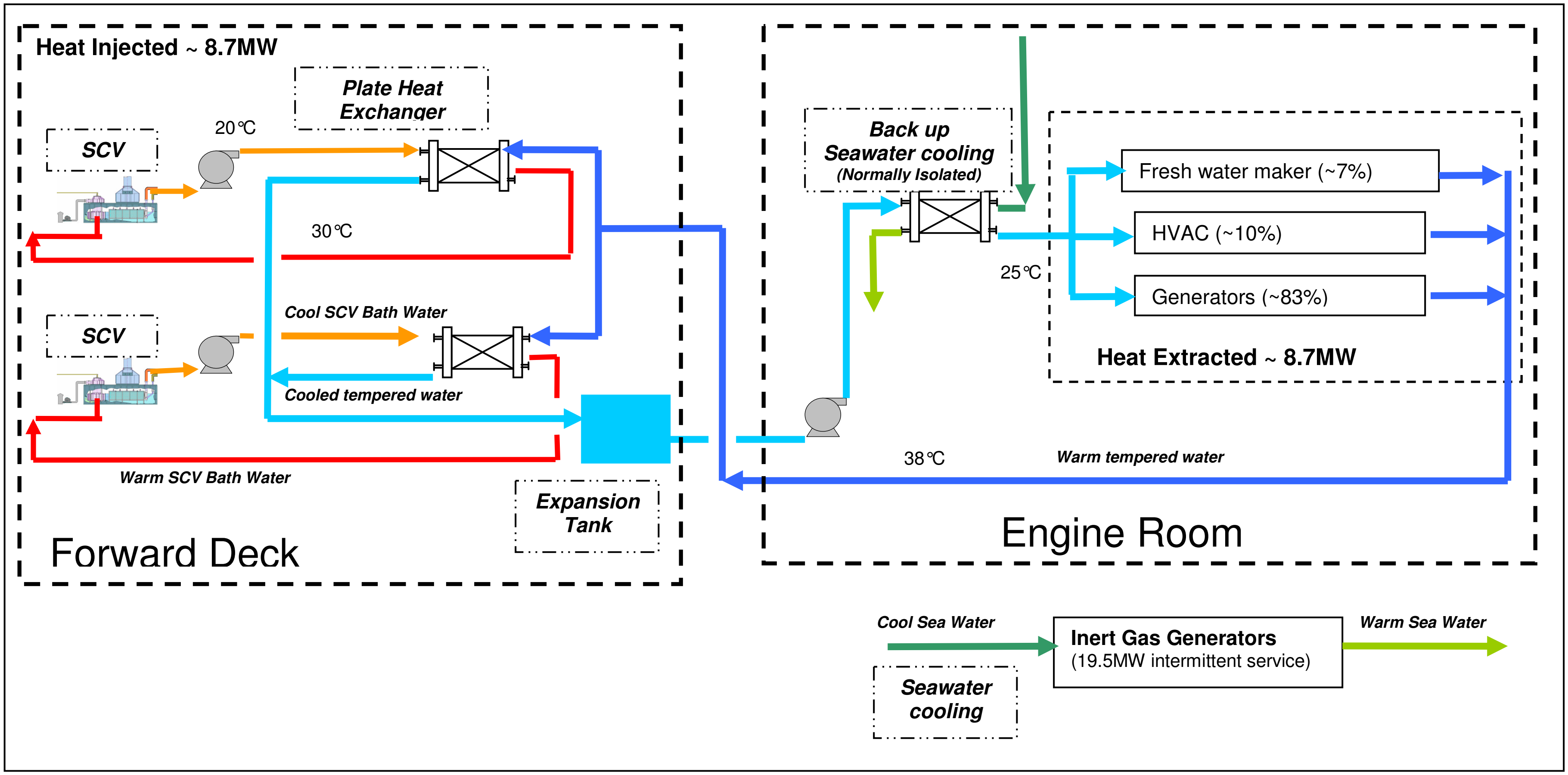
4 SYSTEM DESCRIPTION

The tempered water loop recovers the heat from the engine room and transfers this energy to the SCV water bath. The loop replaces the existing seawater and fresh water cooling circuits in the engine room with a single fluid loop, refer to Figure 4-1.

Only two SCV water baths will be connected to the tempered water loop to provide redundancy and reduce CAPEX. The two SCV bath water loops can be operated either together or independently. The strategy is that either of the modified SCVs will operate whenever SCVs are required, thus recovering heat at all times.

The tempered water circulation pumps (2x 100%, 150kW), located in the engine room, take suction from the tempered water expansion tank, located on the forward deck. The tempered water is pumped through the back up cooler and then through the engine room equipment where it is heated. This warm water is transferred to the SCVs via 300 meters of DN 350 piping along the main deck of the FSRU.

Figure 4-1: SCV water in closed loop cooling system with seawater back up system



At the SCVs, the tempered water loop cools via heat exchangers, transferring heat to the SCV water bath loop, which is circulating on the opposing side. The heat exchange system will include a temperature control system to keep the return cooling water at the correct temperature

The SCV bath water temperature is normally 20°C. The warm water will enter the SCV water bath at approximately 30°C. The cooled tempered water returns to the expansion tank and then the engine room via 300 meters of DN 350 piping on main deck. The tempered water loop will enter the engine room machinery at 25°C and return to the forward deck at 38°C.

The Tempered water loop is closed low pressure system normally operating at a pressure of 500 KPag.

For the design case of 800 MMscfd four SCVs will normally be operated. In the event of both SCVs being out of service, the back-up cooler in the engine room cools the tempered water using sea water.

5 METHODOLOGY

The following items were assessed for the system modification.

- Develop and validate design concepts
- Confirm additional equipment required, including required sizes based on 'full capacity' flow rates (future expansion case) with 4 generators running.
- Capital cost estimates for the system modification were conducted based on equipment sizes only.
- Estimate percentage of fuel gas saving was based on normal production rate (800 MMscfd) with a 30% reduction to allow for partial equipment loads.
- Estimate benefits to the environment as reduction in air emissions, due to the fuel gas savings, using percentage change in fuel gas for each parameter.
- Model the warm seawater plume dispersion from the seawater cooling system (assumes the tempered cooling loop using the SCVs is unavailable). Seawater flow rates have been increased to achieve a maximum differential temperature with the receiving water body of a maximum 20°F (11°C) to comply with the California Thermal Plan.
- Model the warm seawater plume dispersion from the IGG cooling system. Seawater flow rates have been increase to achieve a maximum differential temperature with the receiving water body of a maximum 20°F (11°C) to comply with the California Thermal Plan.
- Identify any outstanding issues

6 DISCUSSION

The original seawater cooling loop uses ambient seawater, which is passed through plate heat exchangers, thus cooling the engine room equipment and heating the seawater. The bulk of the heat transfer to the seawate occurs in the IC generators for the engine jacket water cooling. In the original design, each IC generator unit is supplied with a separate tempered water/ seawater exchanger and a pump for heat transfer.

With this new tempered water loop, the seawater system is retained as a backup (in the event that the SCVs are down). However, the tempered water loop is now integrated with the IC generators and the number of pumps is reduced although the tempered water pumps are now larger in size. The water borne noise levels from these new tempered water pumps in the engine room is not considered significant compared with the levels from the original design. Additional pumps are on the SCV are also required on the SCV on the forward deck but they will have no affect on the water borne noise levels.

The use of a tempered water loop between the engine room and the SCV bath water requires modifications to standard vendor packages. The vendors of the SCVs have confirmed that they are developing similar schemes for heat integration with other customers. Similarly, the use of tempered water loops for the IC generators are standard.

The proposed scheme appears to be technically feasible and will result in a seawater cooling system that will operate intermittently as a backup. The result is the reduction in seawater intake and discharge from the FSRU with a very significant reduction of the impact on the marine environment.

6.1 EQUIPMENT SIZING

The additional equipment required for the system modification is shown in Table 6-1. Note that the current seawater cooling system will remain as the backup system, but has been modified to meet the Californian Thermal Plan.

Table 6-1: Additional Equipment Required

Equipment Item	Number / length	Capacity/Size	Electrical Load	Duty
Pumps				
Tempered Loop Pumps	2	100%	150KW	
SCV bath water pumps	2	100%	55KW	
Piping				
Tempered Loop Piping	600 m	350 DN		
SCV Bath Loop Piping	100 m	200 DN		
Plate Heat Exchangers (additional)	2	100%		12.7MW
Expansion Tank (Tempered Cooling Loop)	1	950 DN		

The seawater pumps are expected to be smaller than stated currently due to the reduction in duty. This reduction will offset the additional equipment and the overall change in electrical load is estimated to be negligible.

During normal operation the seawater pumps will be shut down with the tempered water and SCV bath pump operating. There is no significant change in the electrical load expected.

When the seawater back-up is required, the seawater pumps and tempered water pumps will operate with the SCV pumps shutdown, however the power requirement of the pumps are low compared to the overall electrical demand.

6.2 COST ESTIMATE (CAPEX AND OPEX)

A Capital cost estimate based on the above equipment sizing and installation costs is approximately $5,000,000 ±25% contingency.

The changes to operating costs of the FSRU could not be estimated as part of this study.

6.3 FUEL GAS SAVINGS

Fuel gas savings are a direct consequence of the engine room heat recovery.

At 800 Mscfd, the maximum available heat is 8.7 MW. However a 30% reduction was applied to account for equipment that is partially loaded or intermittent at the production rate. Fuel gas savings were therefore based on this 30% reduced rate, 6 MW of recoverable heat.

One SCV has a duty of 32 MW. The reduction in fuel gas is direct function of reduced duty; therefore, 6MW heat transferred to the SCVs will reduce fuel consumption to 26 MW equivalent from the original 32 MW.

The table below shows the overall fuel gas reduction for 4 SCVs required for the export of 800 MMscfd, (131 MW total duty).

Table 6-2: Overall Fuel Gas Savings

800 MMscfd Base Case	Reduction in fuel gas MMscfd	SCV Fuel Gas Reduction
8.7 MW heat recovery	0.75	6%
6 MW heat recovery	0.52	4%

6.4 ENVIRONMENTAL IMPACT REDUCTION

As a direct result of the reduction in fuel gas consumption, the emissions for the facility will reduce. Environmental savings estimated due to the reduced fuel gas required for the SCVs for this solution are shown below in Table 6-3. A definitive assessment of the values for environmental emissions reduction from the facility is outside the scope of this report.

Table 6-3: Emissions Reduction

800 MMscfd Base Case	SCV Emissions Reduction	FSRU Emissions Reduction
8.7MW heat recovery	6.4%	6.4%
6 MW heat recovery	4.6%	4.5%

6.5 SEAWATER DOSING

Reduction in seawater usage will lead to a reduction in inhibitor chemicals required to manage marine growth. The current seawater cooling system will only be required as a backup system and therefore will no longer require inhibitor chemicals on a continuous basis. The tempered water system is a closed loop system and the chemicals required to maintain the system are not discharged to the environment, only requiring normal make-up maintenance.

Chemical dosing of the cooling seawater to inhibit fouling by marine growth is 50 µg/l of hypochlorite and 5 µg/l copper. Seawater intake requirements for the normal operation case (800 MMscfd gas production) are reduced from 225 kg of hypochlorite and 22.5 kg of copper per year to 3.25kg of hypochlorite and 0.325kg of copper per year.

When the system is not in use it is flushed with fresh water, therefore there is no requirement for chemical dosing of the seawater system during this time.

The expected reduction in discharge of seawater from the system is estimated to be approximately from 4,500,000 m^3/year to 65,000 m^3/year (normal operation, 800 MMscfd gas production based on a total of 4 days of SCV down time), and from 6,800,000 m^3/year to 93,000 m^3/year (for the increased production rate of 1200 MMscfd gas production based on a total of 4 days of SCV down time).

There is no change to the seawater requirement of the IGG of 158,400 m³ per year based on a total of 4 days operation.

Total sea water volume discharged is 224,400 m³ per year based on normal operation.

6.6 SEAWATER DISCHARGE PLUME MODELLING

The effect of the flow from the seawater cooling system exit temperatures and dispersion of this warm water to the environment was assessed. This assessment has been conducted in accordance with the Californian Thermal Plan, which allows a maximum differential temperature with the receiving water body of a maximum 20°F (11°C).

The effects of the discharge plume were modelled using Visual Plume, the USEPA dispersion software.

Assumptions used in the model are:

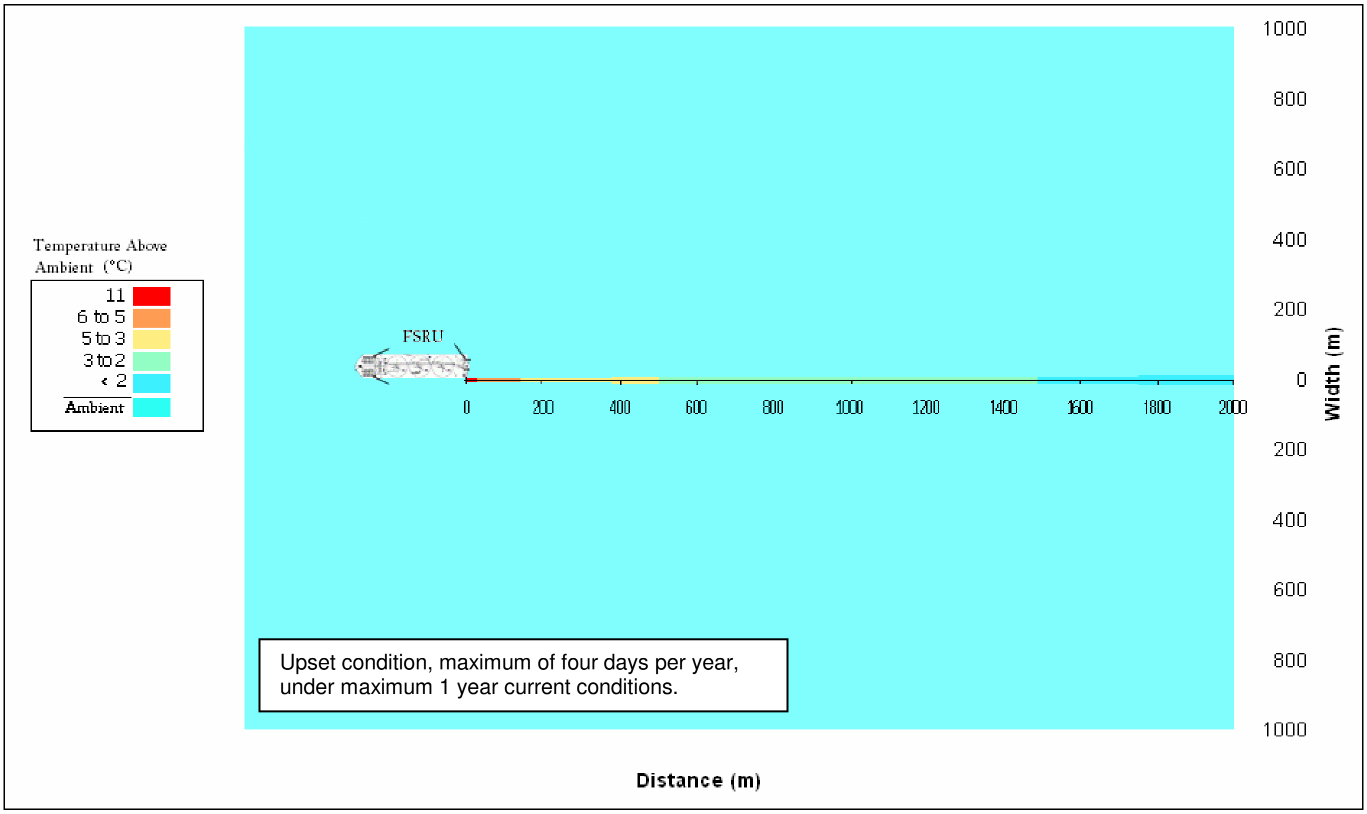
- The plume is in steady state;
- Successive elements follow the same trajectory;
- Ambient water temperature was assumed to remain constant in time and space at 17°C;
- The water discharge point is assumed to be perpendicular to the ship and horizontally aligned at a depth of 0.5 m below the water surface, appendix B.
- Farfield dispersion coefficient of 0.0003 was applied, which is considered to be representative for ocean conditions (USEPA, 2001). For open ocean the dispersion coefficient can range between 0.0001 to 0.0005 $m^{2/3}/s$ (USEPA, 2001).
- The average ambient seawater temperature has been chosen as 17°C.

Visual Plumes UM3 was the chosen dispersion model as it is able to take into account the ambient current and temperature, seawater discharge velocity and temperature. UM3 also proved to be more conservative when compared to another Visual Plumes module for single port submerged discharges (DKHW).

Relevant scenarios for seawater dispersion as presented below were assessed. The seawater velocity of the receiving body was modelled for the 1 year maximum current (1.35 knots) and half of the 1 year maximum current (0.675 knots). It should be noted that the annual average current at the proposed location is 0.25 knots. The maximum differential temperature of the discharge is 20°F above ambient (11°C):

- Case 1: 800 MMscfd (normal operating case), seawater demand of 687 m³/hr.
- Case 2: 1200 MMscfd (future / maximum operating case), seawater demand of 965 m³/hr
- Case 3: IGG demand, seawater demand of 1650 m³/hr

Figure 6-1: 800 MMscfd (gas production rate) plume dispersion, receiving water 1 year maximum current. (1.35 knots)



Plume dispersion for case 1 is shown in Figure 6-1 for a 1 year maximum current. These results represent worst case conditions with a long, thin plume. However, this condition is unlikely to occur simultaneously as the requirement for IGG or back up seawater. The results for all plume models of the 1 year maximum current are presented in Appendix A1. For all cases the discharge plume cools to 4℃ within 250 meters (7℉ within 850 ft) and 2℃ within 1500m (4℉ within 5000 ft) of the discharge point. For reference, the FSRU length is 293 meters.

Results of the plume models for half of the 1 year maximum current are presented in Appendix A-2. In all cases the discharge plume cools to 2℃ within 225 meters (4℉ within 750 ft) and 1℃ within 1000m (2℉ within 3300 ft) of the discharge point. This is the more realistic scenario as the annual average current is 0.25 knots and the plume dispersion therefore complies with the California Thermal Plan under these conditions.

In addition the model does not take into account the natural mixing that will occur due to wave motion, which is expected to accelerate the mixing and reduce temperatures even further.

7 CONCLUSIONS

BHPB requested a review of the seawater cooling system to find a way of reducing seawater intake and discharge. The design solution is to install a closed-circuit tempered water loop. This will reduce the current seawater cooling system from a continuously operating system to an intermittent back up system.

The tempered water loop will transfer heat energy generated by engine room equipment to the LNG vaporisers (SCVs) This heat recovery principle option has the additional benefit of reducing fuel gas consumption by 4% (0.5 MMscfd), air emissions and SCV water disposal by 4%. The CAPEX has been estimated at $US 5Million ±25%; reduction in OPEX could not be estimated.

The use of a tempered water loop between the engine room and the SCV bath water requires modifications to standard vendor packages; however the vendors of SCVs have confirmed that they are investigating similar heat integration schemes in existing facilities with other customers.

Plume model analyses of the seawater discharge were conducted for the normal and future operating cases (when the SCVs are unavailable) and during inert gas operation. Seawater currents at the 1 year maximum (1.35 knots), and half of the 1 year maximum (0.675 knots) were used.

Modelling for 1 year maximum current shows the discharge seawater temperature cools to 4°C within 250 meters (7°F within 850 ft) of the discharge point and to 2°C within 1500 meters (4°F within 5000 ft) from the discharge point.

Modelling for half the 1 year maximum current show the discharge seawater temperature cools to 2°C within 225 meters (4°F within 750 ft) of the discharge point and to just over 1°C within 1000 meters (2°F within 3300 ft) from the discharge point for. This is the more realistic scenario and complies with the Californian Thermal Plan.

8 REFERENCES

1. 05876-PR-TC-002, Fuel Gas Consumption, 13 July 2005
2. ‘Statement of Basis for Proposed Clean Air Act Permit to Construct Cabrillo Port’, The United States Environmental Protection Agency - Region 9, May 2006
3. ‘Water Quality Control Plan for Control of Temperature in the Coastal and Interstate Waters and Enclosed Bays and Estuaries of California’ State Water Resources Control Board.

APPENDIX A:

Summary of Plume Models (Cases 1, 2, and 3 for Maximum 1 year Seawater current and half maximum 1 year seawater current)

Table A-1: Summary of Visual Plume Models (Cases 1, 2, and 3, using maximum 1 year seawater current, 1.35 Knots)

		Case 1: 800 MMscfd		**Case 2: 1200 MMscfd**		**Case 3: IGG**	
far field dist		**∂ Temp**	**width**	**∂ Temp**	**width**	**∂ Temp**	**width**
(m)	(ft)	(°F)	(ft)	(°F)	(ft)	(°F)	(ft)
0	0	19.80	0.00	19.80	0.00	19.80	0.00
25	82	9.97	3.66	10.98	3.68	11.49	3.68
50	164	9.83	4.02	10.82	4.04	11.33	4.05
75	246	9.50	4.35	10.46	4.37	10.95	4.38
100	328	9.11	4.66	10.04	4.68	10.50	4.68
125	410	8.72	4.94	9.61	4.97	10.06	4.97
150	492	8.35	5.21	9.21	5.24	9.64	5.24
175	574	8.02	5.47	8.84	5.50	9.25	5.50
200	656	7.71	5.72	8.50	5.74	8.90	5.75
225	738	7.44	5.95	8.20	5.98	8.58	5.99
250	820	7.18	6.18	7.92	6.21	8.29	6.21
275	902	6.95	6.40	7.67	6.43	8.03	6.43
300	984	6.74	6.61	7.43	6.64	7.79	6.65
325	1066	6.55	6.81	7.22	6.85	7.56	6.85
350	1148	6.37	7.01	7.02	7.05	7.36	7.05
375	1230	6.20	7.21	6.84	7.24	7.17	7.25
400	1312	6.05	7.40	6.67	7.43	6.99	7.44
425	1394	5.91	7.58	6.52	7.61	6.83	7.62
450	1476	5.78	7.76	6.37	7.80	6.67	7.80
475	1558	5.65	7.93	6.23	7.97	6.53	7.98
500	1640	5.54	8.11	6.10	8.14	6.39	8.15
1000	3280	4.10	10.99	4.52	11.04	4.73	11.05
1500	4921	3.40	13.26	3.75	13.32	3.92	13.33
2000	6561	2.96	15.20	3.27	15.26	3.43	15.28

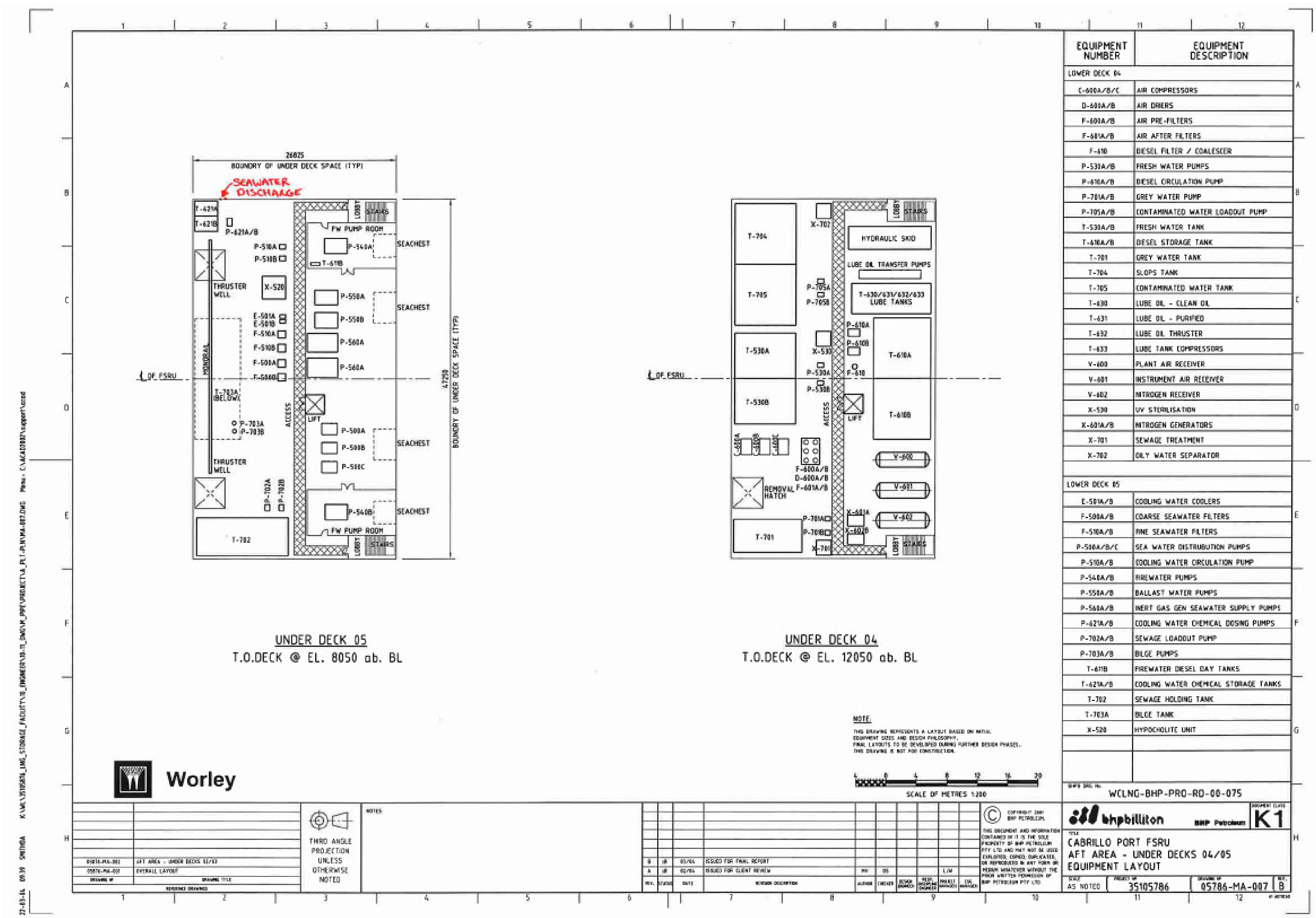
Table A-2: Summary of Visual Plume Models (Cases 1, 2, and 3, using half maximum 1 year seawater currents, 0.675 knots)

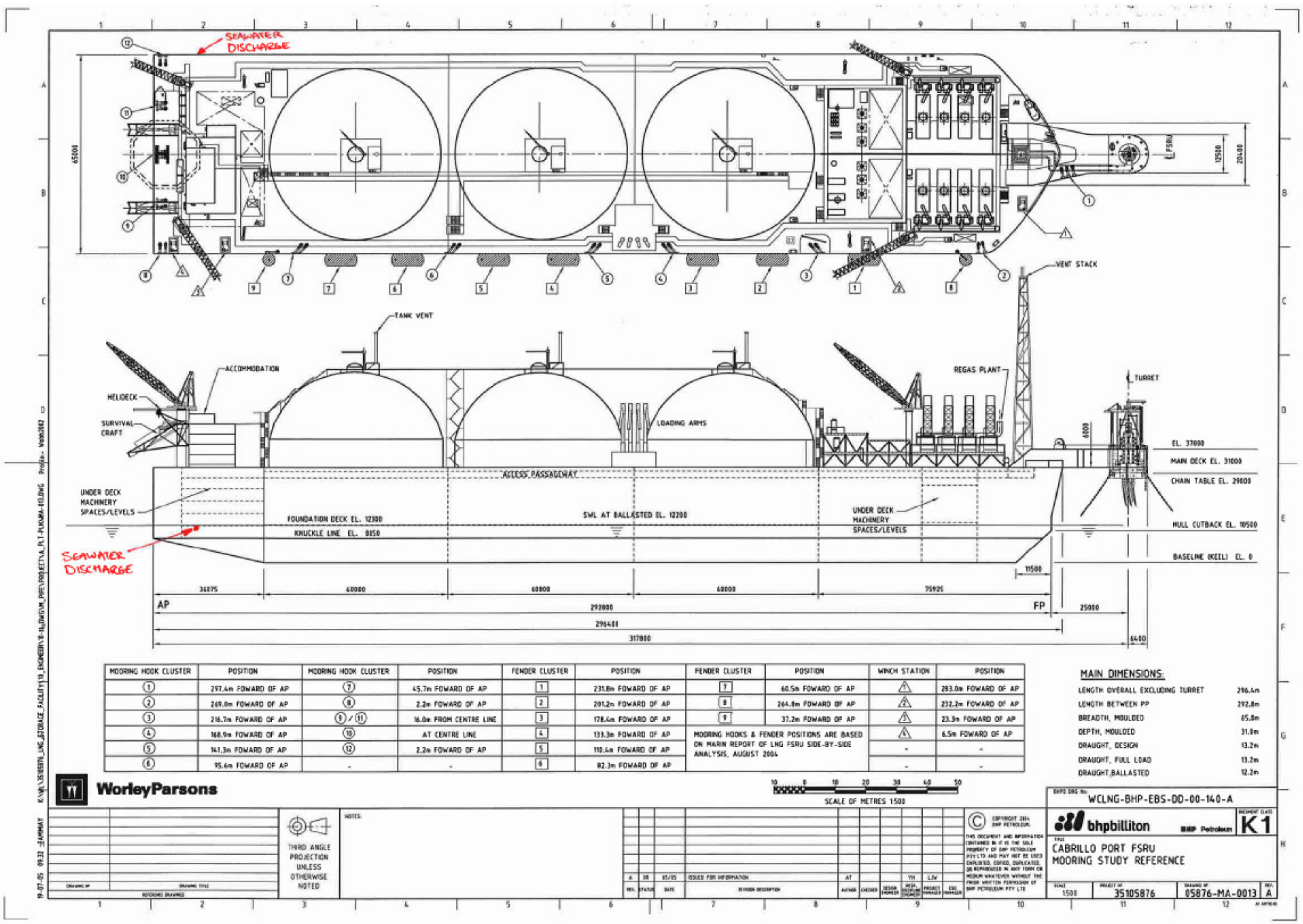
		Case 1: 800 MMscfd		Case 2: 1200 MMscfd		Case 3: IGG	
far field dist		∂ Temp	width	∂ Temp	width	∂ Temp	width
(m)	(ft)	(°F)	(ft)	(°F)	(ft)	(°F)	(ft)
0	0	19.80	0	19.80	0	19.80	0
25	82	11.35	4.01	10.98	3.68	10.98	3.68
50	164	10.52	4.64	10.82	4.04	10.82	4.04
75	246	9.65	5.20	10.46	4.37	10.46	4.37
100	328	8.91	5.70	10.04	4.68	10.04	4.68
125	410	8.29	6.16	9.61	4.97	9.61	4.97
150	492	7.79	6.59	9.21	5.24	9.21	5.24
175	574	7.36	7.00	8.84	5.50	8.84	5.50
200	656	6.99	7.38	8.50	5.74	8.50	5.74
225	738	6.67	7.74	8.20	5.98	8.20	5.98
250	820	6.39	8.09	7.92	6.21	7.92	6.21
275	902	6.14	8.42	7.67	6.43	7.67	6.43
300	984	5.92	8.74	7.43	6.64	7.43	6.64
325	1066	5.72	9.05	7.22	6.85	7.22	6.85
350	1148	5.54	9.35	7.02	7.05	7.02	7.05
375	1230	5.38	9.64	6.84	7.24	6.84	7.24
400	1312	5.23	9.92	6.67	7.43	6.67	7.43
425	1394	5.09	10.19	6.52	7.61	6.52	7.61
450	1476	4.96	10.46	6.37	7.80	6.37	7.80
475	1558	4.84	10.72	6.23	7.97	6.23	7.97
500	1640	4.73	10.97	6.10	8.14	6.10	8.14
1000	3280	3.42	15.17	4.52	11.04	4.52	11.04
1500	4921	2.82	18.44	3.75	13.32	3.75	13.32
2000	6561	2.45	21.20	3.27	15.26	3.27	15.26

APPENDIX B:

Seawater Discharge Point from FSRU

WorleyParsons bhpbilliton





MOORING HOOK CLUSTER	POSITION	MOORING HOOK CLUSTER	POSITION	FENDER CLUSTER	POSITION	FENDER CLUSTER	POSITION	WINCH STATION	POSITION
1	297.4m FOWARD OF AP	7	45.7m FOWARD OF AP	1	231.8m FOWARD OF AP	7	60.5m FOWARD OF AP	1	283.0m FOWARD OF AP
2	269.0m FOWARD OF AP	8	2.2m FOWARD OF AP	2	201.2m FOWARD OF AP	8	264.8m FOWARD OF AP	2	232.2m FOWARD OF AP
3	216.7m FOWARD OF AP	9 / 11	16.0m FROM CENTRE LINE	3	178.4m FOWARD OF AP	9	37.2m FOWARD OF AP	3	23.3m FOWARD OF AP
4	168.9m FOWARD OF AP	10	AT CENTRE LINE	4	133.3m FOWARD OF AP	MOORING HOOKS & FENDER POSITIONS ARE BASED ON MARIN REPORT OF LNG FSRU SIDE-BY-SIDE ANALYSIS, AUGUST 2004		4	6.5m FOWARD OF AP
5	141.3m FOWARD OF AP	12	2.2m FOWARD OF AP	5	110.4m FOWARD OF AP			-	-
6	95.6m FOWARD OF AP	-	-	6	82.3m FOWARD OF AP			-	-

APPENDIX C:

Summary Cooling Water Usage

Table C-1: Reduced Seawater Usage Based on 4 days per year Seawater Cooling System Operation

Calculation Sheet

WorleyParsons resources & energy

Calc no	05876-PR-TC-007	**File**	PR-TC-00
Elec file location	K:\WL\35105876_LNG_Storage_Facility\10_Engineer\10-08_calc\Process\PR-TC-006-pipeline m		
Project title	Cabrillo Port LNG	**Proj no**	351/0587
Customer	BHPBilliton LNG International	**Phase/CTR**	9514
Calculation title	Cooling Water Study	**Page**	6 of

Results/Summary

SEA WATER COOLING SYSTEM

				Including Inert Gas Generator	
		800 MMSCFD LNG	**1200 MMSCFD LNG**	**800 MMSCFD LNG**	**1200 MMSCFD LNG**
Inlet Temperature	°C	**20**	**20**	**20**	**20**
Number of Generators		2	3	2	3
Tempered Water Cooling Loop					
Total Duty	kW	1,069	1,069	1,069	1,069
Seawater Cooling Loop					
Generator Duty	kW	3,680	3,680	3,680	3,680
Fresh water maker unit	kW	652	652	652	652
Inert Gas Generation	kW	0	0	21,459	21,459
Total Duty	kW	9,081	12,761	30,540	34,220
Flow Required for a change in temperature of 20°F as per Southern California Thermal Plan					
Total Seawater Cooling Rate	m³/hr	687	965	2,337	2,615
Change in temperature	°C	11	11	11	11
Outlet pipe sizing @ 1 m/s	mm	493	584	909	962
Outlet pipe sizing @ 3 m/s	mm	285	337	525	555
Selected pipe size DN	**mm**	**600**	**600**	**600**	**600**
Outlet velocity	m/s	0.71	1.00	2.42	2.71

Table C-2: Original Seawater System Water Usage based on 365 days per year

Calculation Sheet

WorleyParsons

Calc no	05876-PR-TC-007	File	PR-TC-0(
Elec file location	K:\WL\35105876_LNG_Storage_Facility\10_Engineer\10-09_calc\Process\(Water Material Balan		
Project title	Cabrillo Port LNG	Proj no	351/0587
Customer	BHPBilliton LNG International	Phase/CTR	9514
Calculation title	Cooling Water Study	Page	6 of

Results/Summary

SEA WATER COOLING SYSTEM

				Including Inert Gas Generator	
		900 MMSCFD LNG	1200 MMSCFD LNG	900 MMSCFD LNG	1200 MMSCFD LNG
Inlet Temperature	deg C	20	20	20	20
Number of Generators		2	3	2	3
Tempered Water Cooling Loop					
Total Duty	KW	1,069	1,069	1,069	1,069
Seawater Cooling Loop					
Generator Duty	KW	3,680	3,680	3,680	3,680
Fresh water maker unit	KW	652	652	652	652
Inert Gas Generation	KW	0	0	21,459	21,459
Total Duty	KW	9,081	12,761	30,540	34,220
Cooling Water dT (16 deg C) as per temperatures stated in EIS.					
Total Seawater Cooling Rate	m³/hr	517	776	517	776
Inert Gas generator demand	m³/hr	0	0	1,650	1,650
Total Seawater Demand	m³/hr	517	776	2,167	2,426
Change in temperature	deg C	15	14	12	12
Outlet Temperature	deg C	35	34	32	32
Outlet pipe sizing @ 1 m/s	mm	428	524	875	926
Outlet pipe sizing @ 3 m/s	mm	247	302	505	535
Selected pipe size DN	mm	600	600	600	600
Outlet velocity	m/s	0.54	0.80	2.25	2.51
Flow Required for a change in temperature of 10 deg C					
Total Seawater Cooling Rate	m³/hr	763	1,072	2,413	2,722
Change in temperature	deg C	10	10	11	11
Outlet pipe sizing @ 1 m/s	mm	519	616	924	981
Outlet pipe sizing @ 3 m/s	mm	300	356	533	567
Selected pipe size DN	mm	600	600	600	600
Outlet velocity	m/s	0.79	1.11	2.50	2.82
Flow Required for a change in temperature of 15 deg C					
Total Seawater Cooling Rate	m³/hr	509	715	2,159	2,365
Change in temperature	deg C	15	15	12	12
Outlet pipe sizing @ 1 m/s	mm	424	503	874	915
Outlet pipe sizing @ 3 m/s	mm	245	290	504	528
Selected pipe size DN	mm	600	600	600	600
Outlet velocity	m/s	0.53	0.74	2.24	2.45
Flow Required for a change in temperature of 20 deg C					
Total Seawater Cooling Rate	m³/hr	382	536	2,032	2,186
Change in temperature	deg C	20	20	13	13
Outlet pipe sizing @ 1 m/s	mm	367	435	848	879
Outlet pipe sizing @ 3 m/s	mm	212	251	489	508
Selected pipe size DN	mm	600	600	600	600
Outlet velocity	m/s	0.40	0.56	2.11	2.27
Flow Required for a change in temperature of 25 deg C					
Total Seawater Cooling Rate	m³/hr	305	429	1,955	2,079
Change in temperature	deg C	25	25	13	14
Outlet pipe sizing @ 1 m/s	mm	329	389	832	857
Outlet pipe sizing @ 3 m/s	mm	190	225	480	495
Selected pipe size DN	mm	600	600	600	600
Outlet velocity	m/s	0.32	0.44	2.03	2.15

Duty of Engine Room Equipment

Table 1: Air Compressor Inter-Cooler and Air Compressor After-Cooler Duty

Inter Cooler		
Duty per unit (kW)	72	(CAL-PR-001-A Conceptual)
Number of units online	1.5	
Inter Cooler Total Duty (kW)	107	
After Cooler		
Duty per unit (kW)	49	(CAL-PR-001-A Conceptual)
Number of units online	1.5	
After Cooler Total Duty (kW)	73	
Total Duty (kW)	180	

Table 2: HVAC System Duty

Air Handling/Cooling Duty (kW)	500	Assumed for large system
HVAC Compressor Duty (kW)	100	5:1 ratio
HVAC System Total Duty (kW)	600	Heat load on tempered water loop
Number of units online	1	
Total HVAC System Duty (kW)	600	

Table 3: Fresh Water Maker Cooler

Seawater Heating Value (cp) (kJ/kg.℃)	4.19	(CAL-PR-001-A Conceptual)
ΔT (℃)	35	
Number of units online	1	
Duty (kW)	42.4	
Contingency (%)	30	
Total Duty (kW)	55.1	

Table 4: Inert Gas Generator Duty

Inert Gas Generator Seawater Supply Total Duty (kW)	19508	
Number of units online	1	
Total Inert Gas Generator Seawater Supply Total Duty (kW)	19508	

Table 5 Fresh Water Maker Unit Duty

Potable Water Production Total Duty (kW)	652	
Number of units online	1	
Total Potable Water Production Total Duty (kW)	652	